THE ATMOSPHERE

As plotted from sea level to the exosphere People have long sought to understand, map, and occupy Earth's atmosphere. The Atmosphere: A Guide depicts some human influences on the sky and the accumulated traces left there-whether chemical, narrative, spatial, or political.

Recent efforts to visualize scale owe a debt to Kees Boeke and his 1957 book Cosmic View: The Universe in 40 Jumps. Preceding the first photograph of the Earth taken from space by two years, Cosmic View shares some zooming qualities with the bird's-eye perspective of satellite imagery. Boeke's book is a humane essay on scale, using a sequence of photographs and

drawings to jump in steps from the relative size of the human body up to the scale of the universe and then back to the scale of the atom. Boeke also developed sociocracy, a model for consent-based pedagogy. Cosmic View influenced two films made in 1968; Cosmic Zoom by Eva Szasz and A Rough Sketch for a Proposed Film Dealing with the Powers of Ten and the Relative Size of the Universe by Ray and Charles Eames.

Which sky?

How do science, social attitudes, economics, and politics intersect in the atmosphere? The intangibility of the atmosphere and much of its composition of gases make it appear resilient and forgiving of anthropogenic damage. However, the future of the atmosphere is altered by how people understand, consider, and act upon it in the present. Current and historic visions of the atmosphere frame our relationship to it and send ripples towards the rights of future people to a familiar climate.

Towards a new map

Which atmosphere is it? The biogeochemical or the geopolitical? A global commons or militarized space? Does the difficulty of human occupation of the atmosphere produce a space for projection and speculation? A space of indeterminacy? The Atmosphere: A Guide charts some atmospheric politics and their downward influences.

LAYERS OF THE ATMOSPHERE

EXOSPHERE

600-10.000 KM/375-6.200 MI

The exosphere is the uppermost layer of the atmosphere It is composed mostly of thinly distributed hydrogen and helium, the lightest gases. There is some atomic oxygen near the bottom of the exosphere, which is called the exobase. In the exosphere, satellites can orbit the Earth with little atmospheric drag.

There is no clear boundary between the exosphere and



WHAT PEOPLE SHOULD KNOW

"One of the reasons I study the atmosphere is because it's critical to life. But it's a very, very thin veneer on the surface of the planet. You can go anywhere in the world and take an air sample in what you think is the cleanest place on earth, and it's full of human-produced compounds. We can see all these things that were never there before in the history of the planet. And we can measure it. And so the stuff that people dump into the atmosphere doesn't disappear, doesn't escape to space. And this is relevant for the greenhouse effect, it's relevant for stratospheric ozone depletion, it's relevant for just air pollution in general."

YOU ARE HERE

- Robert Rhew, geochemist, UC Berkeley

POLLUTION

SPACE JUNK + CO₂

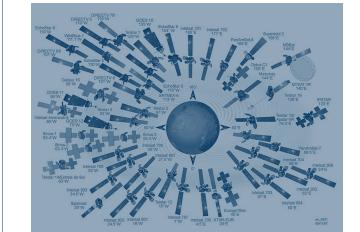
that of solar variability."

By 2018, the Swiss Space Center plans to launch CleanSpace One, a robot spacecraft designed to grab inactive satellite parts and bring them back to Earth.

"Research since the early 1990s has led to the suggestion that increasing carbon-dioxide emissions, from power stations and other terrestrial sources, are increasing the orbital lifetimes of defunct satellites and debris in the lower-altitude orbits. Observations and modeling support the theory that CO2 emissions have led to a cooling of the thermosphere (at altitudes between 85 and 600 km) and a consequent reduction in density, which reduces the frictional effect on orbiting objects. The hypothesis is that thermospheric cooling could continue for the next hundred years, despite CO2 emission controls, by which time the effect would be comparable with

- Mark Williamson, Space: The Fragile Frontier

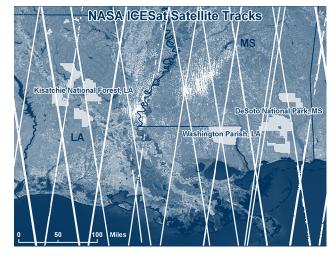
SPATIAL POLITICS



SATELLITES

"Investigate satellites, learn their names, who owns them, what they do, how they have been used. There is a need for more satellite literacy. Contest the militaristic and corporate appropriation of satellites with more art, activism, dreaming, and experimentation. Imagine how the use of satellites in the public interest might be defined."

> - Lisa Parks, Ph.D. Film and Media Studies UC Santa Barbara



REMOTE SENSING

SATELLITE REMOTE SENSING

Remote sensing satellites use sensors to observe the Earth from the exosphere. Remote sensing has become increasingly important for monitoring human impacts on the global environment. Environmental applications include tracking the effects of climate change on glaciers, sea ice, and for-

From 2003 to 2009, NASA's ICESat satellite measured ice sheet mass balance, cloud and aerosol heights, topography, and forest cover. When ICESat's primary sensor failed in 2001, it was crashed by "de-orbit burn" over the Barents Sea and replaced by IceBridge, an airborne survey of Earth's polar ice. In 2009 and 2011, two of NASA's Earthobserving satellites, Glory and the Orbiting Carbon Observatory (OCO), intended to further climate research efforts. crashed during their respective launches. This was a major setback for improving the accuracy of climate models. The launch of ICESat-2 is planned for 2017.

CLIMATE CHANGE

THE SPECULATIVE

Scenarios are images of the future or alternative futures. Used to explore possible ways the climate may change in the future in a range of time scales, climate scenarios predict how "temperature, precipitation, sea level, and other climatic variables may change" over time as a result of human and natural climate drivers. Climate scenarios also factor in human beliefs about the climate and how attitudes towards

the future impact the future climate and atmosphere. While it would be difficult to sum up the total impact of human worldviews on the atmosphere, anthropogenic greenhouse gas concentration might be a crude metric. In April 2015, the data for atmospheric carbon dioxide (CO2) as measured at the Mauna Loa Observatory, Hawaii was 403 parts per million (ppm). What will the climate be like in 100 years? In 1,000 years? Uncertainty is high.



AIRSPACE

OUTER SPACE TREATY OF 1967

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, or the Outer Space Treaty, forms the basis of international space law. It forbids governments from claiming rights to, or control over, resources beyond the Earth's atmosphere, as the "common heritage of humankind." It also stipulates free access to all areas of celestial bodies. While signatories to the treaty are not allowed to make claims of sovereignty by occupation of celestial bodies, a state retains control over artificial objects it has launched. States are also liable for damage or pollution caused by their activities in space. The treaty bars signatories from putting weapons of mass destruction in Earth's orbit, on the Moon, or in outer space. It also limits the use of the Moon to peaceful purposes, barring military bases, training, testing, or occupation. However, it does not



ELECTROMAGNETIC SPECTRUM

THE SOUND OF SPACE WEATHER

had closed in...

Stephen P. McGreevy has been recording very low frequency (VLF) and extremely low frequency (ELF) electromagnetic (radio) wave signals in remote areas since the 1990s. "Unlike sound waves, which are vibrations of air molecules that our ears are sensitive to, natural radio waves are vibrations of electric and magnetic energy which-though occurring at the same frequencies as sound-cannot be listened to without a fairly simple radio receiver to convert the natural radio signals directly into sound," says McGreevy. He has a significant body of recordings of auroras, meteor showers, and VLF "whistlers," which he defines as "bursts of ELF/VLF radio energy initiated by lightning strikes which 'fall' in pitch" archived at auroralchorus.com. Of the photo above, he said "Listening to whistlers at Lee Flat in the smoky desert that morning was eerie-usually we have such good desert visibility-the smoke made it feel like the world

THERMOPAUSE

THERMOSPHERE

90-600 KM / 56-375 MI

and free-floating electrons.

The thermosphere is technically the warmest layer of the atmosphere. Influenced by solar activity, it expands and contracts daily. Here, gases can heat to 2,500°C (4,530°F) in daytime. But heated gas molecules are so thinly dispersed

that their influence on air temperature is negligible.

The ionosphere is an ion-rich area of the upper atmosphere, extending across the mesosphere, thermosphere, and exosphere from 60 to 300 km (37 to 190 miles) above the Earth's surface. In the ionosphere, the sun's energy, as ultraviolet radiation, breaks up air molecules to create plasma, made up of ions (atoms with missing electrons)

The International Space Station orbits in the upper thermosphere. The upper thermosphere and exosphere meet at the thermopause, also called the exobase.

ENMOD

Operation Popeve was an American military cloud-seeding operation intended to extend the monsoon season over Laos during the Vietnam (American) War. Crafted in response to Operation Popeye, the 1976 Environmental Modification Convention (ENMOD) prohibits any hostile use of environmental modification techniques.

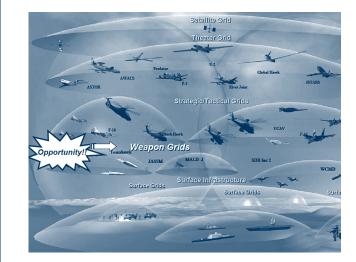
As defined in Article II of the Convention, "environmental modification techniques' refers to any technique for changing-through the deliberate manipulation of natural processes-the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space." The Convention entered



SHRINKING SKY

Although CO2 emissions cause warming in the lower atmosphere, they can cause the thermosphere to cool. Cooling is already reducing the density of the thermosphere, causing an overall contraction.

Since the 1940s, the thermosphere, which warms and expands significantly by day and cools and shrinks at night,



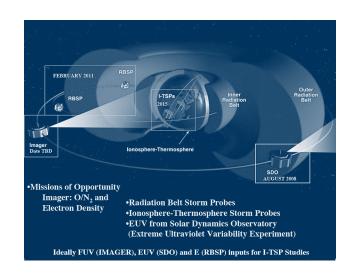
WEAPON GRIDS

While difficult to inhabit, the atmosphere is occupied and controlled. From symbols of state power and cooperation, to spheres of remote control, the atmosphere is divided by maps, networks, and weapon grids.

These include American attempts to exercise military control in the upper and lower atmosphere, such as the never-fullydeveloped Strategic Defense Initiative (Star Wars), which was to include space-based weapons, and the now-defunct Distant Early Warning (DEW) Line, a Cold War system of

As represented in the above 2007 U.S. Department of Defense rendering, networked "weapon grids" are a vision of total militarization of the atmosphere, extending from the exosphere to sea level.

radar stations positioned in the Canadian High Arctic.

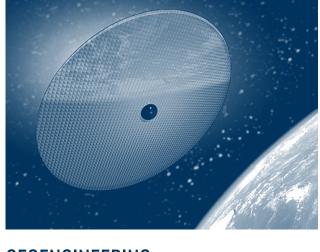


IONOSPHERE-THERMOSPHERE PROBES

Delayed from a planned 2012 launch by NASA, a pair of lonosphere-Thermosphere Storm Probes (I-TSP) may eventually "study distributions of ionospheric and thermospheric densities, geomagnetic disturbances, and ionospheric irregularities" by bouncing high-frequency (HF) radio waves off the ionosphere. The ionosphere is broken into four regions: D, E, F1, and F2. The D region (50-90 km), which readily absorbs AM radio waves, disappears at night, along with the E (90-120 km) and F1 (150-210 km) regions. Only the F2 (210-800km) region is present 24 hours of the day, making it the most important region for HF radio propagation. If launched, the I-TSP probes will orbit near peak ion density (400-450 km), taking "measurements of plasma density, drifts, irregularities, neutral densities, and winds." These properties of the ionosphere-thermosphere impact

communication, guidance, and spacecraft orbits, and poten-

tially affect ozone and climate.



GEOENGINEERING

Geoengineering is the deliberate "rearranging [of] the Earth's environment on a large scale to suit human needs." This includes proposed and largely untested climate-altering technologies such as pumping sulfur into the stratosphere, liquefying and sequestering carbon dioxide in the deep sea, "fertilizing" oceans with iron to produce plankton blooms, and positioning a giant mirror in orbit over Greenland to reflect sunlight with the aim of stopping ice from melting.

Geoengineering is often promoted as an opportunity to utilize large-scale technology to slow or stop climate change. At the same time, these technologies have unpredictable and potentially irreversible implications. With weather modification as a potential weapon, they may contravene the 1976 UN Environmental Modification Convention (ENMOD). In addition, geoengineering legitimates continued extraction and



ban the placement of conventional weapons in Earth's orbit.

KÁRMÁN LINE (100 KM / 62.1 MI)

and thus a lack of drag.

The Kármán line is an internationally designated altitude boundary used to define where space begins. Named for engineer and physicist Theodore Van Kármán, the Kármán line is the minimum height at which free fall and orbiting is possible. It is also the upper atmospheric limit for

air sports, separating aeronautics from astronautics. While

aeronautics need the presence of sufficient atmosphere to

be viable, astronautics instead need a lack of atmosphere,

Auroral glow is created by high-energy particles from the sun striking Earth's atmosphere as solar wind, colliding with, exciting, and ionizing oxygen atoms. The strength of the solar wind determines the intensity of the aurora. Red oxygen aurora (150 km+) are above green oxygen aurora (100 km–150 km). A daily forecast of expected geomagnetic activity is provided by the Geophysical Institute at the Univer-

Auroras are light displays in the upper atmosphere that occur mostly from 100 km to 300 km, high above polar regions. They resemble shifting red or green transparent arcs or rippling curtains that appear to hang from and move across the sky. Earth's magnetic field is much stronger near

particles, and makes it far more common to witness auroras

the magnetic north and south poles, which attracts charged

sity of Alaska Fairbanks.

MESOPAUSE

MESOSPHERE

50-90 KM / 31-56 MI

Sahara Desert.

Cold and dry, the mesosphere is the least researched layer of the atmosphere. It is the coldest layer of the lower atmosphere, where temperatures drop with increasing altitude to a low of around -100°C (-130°F), creating conditions that freeze water vapor into ice clouds. The mesosphere is very dry-one hundred million times drier than air from the

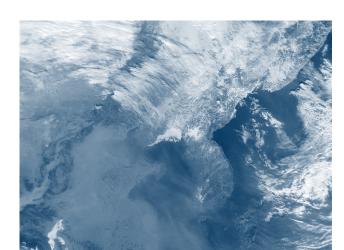


NOCTILUCENT CLOUDS

Noctilucent or "night-shining" clouds can occasionally be seen very high in the sky at sunset, if sunlight hits them when the sun is four to sixteen degrees below the horizon. The clouds consist of tiny ice crystals about the size of the particles in cigarette smoke. Considered by some a symptom of a changing climate, noctilucent clouds (also known as Polar Mesospheric Clouds) begin to occur at a height upwards of 80 km (50 mi) in the mesosphere. They were first observed in 1885, about two years after the eruption of Krakatoa shot plumes of volcanic ash up to 80 km high. At that time, the clouds were only seen in latitudes above 50°, in places like Scandinavia, Russia, and Britain. More recently, they have been seen as far south as Utah and

Colorado. In the northern hemisphere, noctilucent cloud

season runs from mid-May to the end of August.

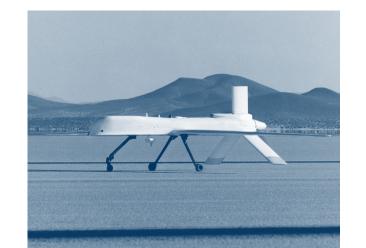


GENEVA CONVENTION ON AIR POLLUTION

The 1979 Geneva Convention on Long-Range Transboundary Air Pollution was a response to industrial emissions from central Europe causing acid rain in Scandinavia and a broader scientific understanding in the 1970s that air pollution could be transported thousands of miles from where it was emitted. The aim of the Convention was that "parties shall endeavor to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution."

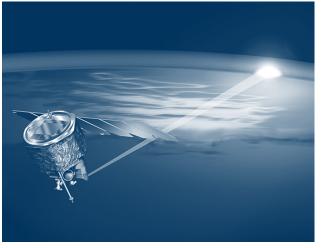
Since it came into force in 1983, the Convention has been extended by eight protocols that identify measures to be taken to cut emissions of specific air pollutants, including heavy metals, nitrogen oxides, volatile organic compounds,

and persistent organic pollutants.



SCIENCEWASH

Dual-use technology describes technologies and goods that share peaceful scientific and military applications. Northrop Grumman Corporation's Global Hawk drone is a high-altitude unmanned aerial vehicle (UAV) that can stay aloft for more than 30 hours. NASA has used the Global Hawk in a project to verify measurements by its auroral atmospheric research satellite. The Global Hawk has also been utilized by the United States military in both the Afghanistan and Iraq Wars. As early as 2010, 7,000 UAVs were in use by the U.S. military across Iraq and Afghanistan for military reconnaissance, surveillance, and for the remote-controlled launch of missiles and bombs from the air.



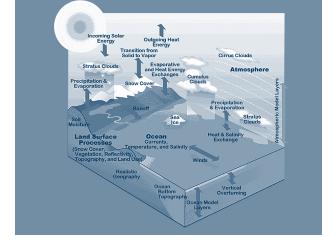
AERONOMY OF ICE IN THE MESOSPHERE

The Aeronomy of Ice in the Mesosphere (AIM) satellite was launched in 2007 by NASA to research noctilucent, or "polar mesospheric" clouds (PMCs). The primary research goal of AIM has been to assist scientists' understanding of why these clouds form, and their relationship to Earth's climate. The satellite's instruments measure the spatial distribution, particle size, and abundance of PMCs, and gather data on temperature and atmospheric chemistry. Since 2007, AIM has revealed that mesospheric ice occurs in a continuous layer of clouds from below 83 km up to 90 km. However, the most significant early finding was that the "startling similarity between the PMC structure observed...and that seen in tropospheric clouds suggests that the mesosphere may share some of the same dynamical processes responsible for weather near Earth's surface." AIM was extended from 2009–2015 to further study the clouds' possible connection



ATMOSPHERIC & CLIMATE JUSTICE

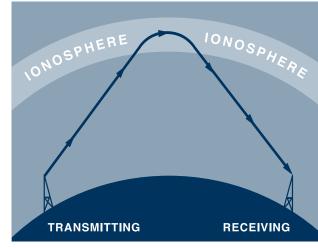
"We are shocked by the level of corruption that the United Nations Framework Convention on Climate Change has reached in allowing corporations to take over the political space and process of climate negotiations." - Alicia Muñoz of Via Campesina in Chile Climate Justice Now! Network Joint Statement



CLIMATE MODEL

Climate models mathematically simulate the interactions of the atmosphere, oceans, land surface, and ice. Climate models can be global, showing general atmospheric circulation, or regional. Multiple climate models are considered simultaneously to provide a predictive range for projected impacts of climate change.

Both simple and complex mathematical scenarios are used by organizations like the Intergovernmental Panel on Climate Change (IPCC) during climate negotiations and in policy recommendations. In 2012, North Carolina's Senate passed a bill restricting the use of predictive modeling of coastal sea level rise scenarios by state planning officials



SKYWAVE (IONOSPHERIC REFRACTION)

Vital for shortwave radio communication, the ionosphere refracts HF radio waves well, making it possible for a receiver to pick up distant signals without satellites or other infrastructure. High frequency (HF) radio signals transmitted at sea level travel up to the ionosphere, where they are reflected back down, allowing over-the-horizon radio com-

munication over long distances.

Signals can skip many times between the Earth and ionosphere, in a process called multihop propagation. Both signal strength and multihop length can vary, influenced by electromagnetic interference and changes in the ionosphere from day to night. Lower levels of the ionosphere disperse at night, making higher reflected, longer distance bounces possible, and allowing AM and shortwave radio signals to be heard at long distances. HF radio frequencies are from 3 to 30 megahertz (MHz).

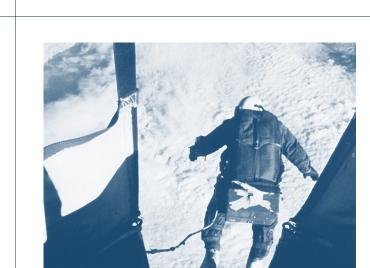
STRATOPAUSE

STRATOSPHERE

around 0°C.

20-50 KM / 12-31 MI The stratosphere has stable atmospheric conditions, largely

lacking the weather, clouds, and air turbulence found in the The ozone layer occupies much of the stratosphere and varies in height worldwide. It is thinner near the equator and thicker over polar regions. The ozone layer traps UV rays, causing the temperature to rise with increasing altitude towards the top of the stratosphere, creating temperatures



JOSEPH KITTINGER (19.5 MI)

"There is a hostile sky above me. Man may live in space, but he will never conquer it." Joseph Kittinger In 1959, Joseph Kittinger made a solo jump in a pressurized suit from the Excelsior III balloon at 102,800 feet (19.5 miles) as part of American military research on the impacts of high-altitude bailout. He made two other highaltitude jumps over the next year, from 76,400 and 74,700

the upward journey.



ARCTIC AIR POLLUTION TRANSPORT Wind currents transport synthetic pollutants like PCBs

feet. Each project had mid-fall incidents, from an uncontrollable high-speed tailspin to the depressurization of a glove in mid-descent. In 2012, Felix Baumgartner jumped from a specialized helium balloon 128,100 feet (24 miles) above the Earth, breaking the sound barrier while in free fall. Joseph Kittinger was his primary radio support during



(polychlorinated biphenyls) and the pesticide DDT Canada, and Europe.

ants of any people on Earth.

(dichlorodiphenyltrichloroethane) to the Arctic from areas of industrial production including China, the United States, These pollutants are responsible for the high concentration of endocrine-disrupting toxins found on the higher end of the Arctic food chain. The blood and fat tissues of Inuit (The People) and other peoples of the Canadian Arctic and subarctic, who eat a largely traditional diet of fish and sea

mammals high in the food chain, contain among the highest

concentrations of PCBs and other persistent organic pollut-



WAR IN THE LOWER ATMOSPHERE

"Mr. Speaker, thick clouds of black smoke from the well fires have been spewing into Kuwaiti skies for over a month, obscuring the sun with air pollutants estimated at 10 times the amount produced by all the industrial and electric generating plants in the United States combined Atmospheric pollution on this scale has not occurred in our history. The Environmental Protection Agency has detected some air pollutants attributed to the gulf fires halfway around the world at its Mauna Loa station in the

Hawaiian Islands." - Congresswoman Nancy Pelosi Excerpt from the Congressional Record

April 16, 1991



DRIFTSONDE

forecasting.

to climate change.

A driftsonde is a specialized high-flying balloon used to gather environmental data from remote parts of oceans that are otherwise inaccessible. The balloon expands to full size as it ascends to 60,000-65,000 feet in the upper stratosphere. It then drifts with prevailing winds for up to a

Dropped from an airplane mid-flight, driftsondes carry instrumentation to collect data on pressure, temperature, and humidity. Instrument packages, called dropsondes, are dropped from the driftsonde, repeatedly relaying information via satellite as they descend. Like radiosondes, driftsondes provide data for weather and climate



OZONE (0_3)

"Ozone is an interesting compound. Many people view it as the central molecule in terms of atmospheric chemistry. In the lower atmosphere, ozone is considered a pollutant because it's harmful to human health and plant life, and it's a major component of smog. In the background atmosphere, though, ozone is essential to form radicals that clean the atmosphere of all its pollutants. So ozone in the troposphere can be considered as a pollutant and as a critical cleaner of the atmosphere. And when you go up into the stratosphere, it's critical to life on this planet, because it absorbs incoming ultraviolet radiation which would otherwise

cause damage to DNA of the cells of living organisms." - Robert Rhew, geochemist, UC Berkeley



DIVERSIONS

Many countries impose demands on airplane flights that overfly their territory. These include fees levied for "flyover

"These fees vary from country to country," says air traffic legal expert Ronald Schmid, quoted in Spiegel Online. "That's why, for instance, routes from Frankfurt sometimes take a zigzag course to Buenos Aires, Argentina, in order to avoid territories with high fees."

In 2007, the United States Department of Homeland Security proposed a requirement for Canadian airlines to hand over passenger lists 72 hours before flights that travel in the path of U.S. airspace, even if the plane and passengers did not intend to land there.



SPECTRUM

The electromagnetic spectrum includes all frequencies of electromagnetic radiation, including radio waves, microwaves, visible and infrared radiation, and gamma waves. By selling permits for exclusive use of a band of the spec-

radio and other electromagnetic waves on certain frequen-Experiments in spectrum autonomy have included the launch of Russian amateur radio satellite ARISSat-1 into low Earth orbit (2011-2012), as part of an educational proj-

ect, and as-yet-unrealized plans for a Hackerspace Global

Grid, including a distributed ground station.

trum, spectrum privatization converts the electromagnetic

spectrum to property, restricting the ability to propagate

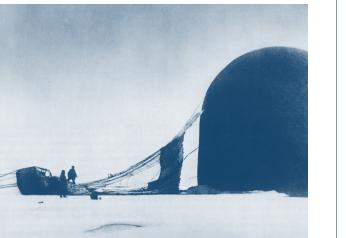
TROPOSPHERE

16 km over the Equator.

0-20 KM / 0-12 MI The troposphere is the lowest part of Earth's atmosphere. It contains up to 80 percent of its gases, and most of its mass and water vapor. It is composed mostly of nitrogen

(78 percent) and oxygen (21 percent), along with trace gases. The bottom part of the troposphere is the only part of the atmosphere that is breathable. The troposphere is turbulent, and, in contrast to the other layers of the atmosphere, is warmest nearest the Earth's

surface. It varies in thickness from 8 km over the poles to



ARCTIC BALLOON EXPEDITION OF 1897

In 1897, balloonist S. A. Andrée led a failed Swedish expedition to the North Pole. They intended to steer their hydrogen balloon by a system of drag ropes to the Pole by way of Svalbard across the Arctic Sea. Their aircraft crashed on pack ice, weighted down by ice accumulation on top of the balloon. Andrée and his travel companions, including playwright August Strindberg's nephew, Nils, died while attempting to trek back across the pack ice. Their disappearance was a mystery until 1930, when the remains of their last camp were discovered on White

Island (Kvitøya), near Svarlbard.



TRANSBOUNDARY AIR POLLUTION

"At least one-third of California's fine particulate pollution -known as aerosol-has floated across from Asia,' says Steve Cliff, an atmospheric scientist at the University of California at Davis. 'In May this year, almost all the fine aerosol present at Lake Tahoe [300 km east of San Francisco] came from China, 'says Tom Cahill, a UC Davis emeritus professor of atmospheric sciences. 'So the haze that you see in spring at Crater Lake [Oregon] or other remote areas is in fact Chinese in origin."





Christmas Island Area, 210 kilotons at 6,970 ft. Atmospheric nuclear bomb tests from 1954 to 1963 produced a persistent cloud of carbon-14 (a radioactive isotope of carbon) that traveled the Earth. Beside doubling the amount of carbon-14 in the atmosphere, atomic



weapons testing left markers of atmospheric militarism

around the world. As a result of eating fruit from trees with

increased carbon-14 uptake, people born in the 1950s

carry more carbon-14 in their brain cells than people born

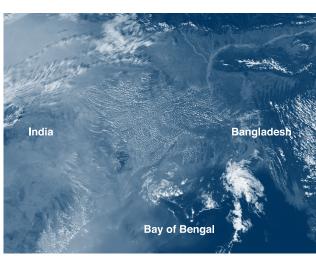
after the 1963 Partial Nuclear Test Ban Treaty.



RADIOSONDE A radiosonde is a balloon-borne instrument platform with radio transmitting capabilities. Like driftsondes, radiosondes carry pressure, temperature, and humidity instrumentation. These sensors gather and send back data about atmospheric conditions during an upward

flight. Data from daily flights are aggregated for a broader picture of changing atmospheric conditions. Radiosondes are launched twice daily near the Oakland airport in California by a private contractor for the National Weather Service (NWS). The NWS is a component of the National Oceanic and Atmospheric Administration (NOAA),

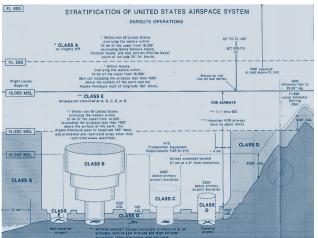
an Operating Unit of the U.S. Department of Commerce.



ATMOSPHERIC BROWN CLOUDS

Atmospheric brown clouds (ABCs) are regional scale plumes of brownish air pollution that appear cyclically, particularly over parts of Asia, Southern Africa, and the Amazon Basin. They contain soot (black carbon), sulfates, and other aerosol components from the combustion of fossil fuels and biomass. ABCs block the Sun's rays, reducing the amount of sunlight reaching Earth's surface by 10 to 15 percent. They also reduce rainfall. Aerosols have the ability to enhance nucleation, so more water vapor is able to stay aloft in clouds and less falls as rain. The light absorbing and scattering impact of these aerosol-laden clouds is complex, contributing to atmospheric solar heating while masking other aspects of climate change. ABCs also decrease the Indian summer monsoon rains, damage human health, increase surface

ozone, and decrease crop production in affected areas.



VERTICAL EXTENT OF SOVEREIGNTY A "complex, crafted network invisible to the spectator on the ground," airspace is divided into three-dimensional regions, which are organized into a series of standardized classes based on access restrictions. There is no international agreement on the vertical extent of sovereign airspace. The United States has suggested that anyone or anything passing more than 50 miles (80 kilometers) high does

not need to request permission to overfly other nations.

The Kármán line, at 62 miles (100 kilometers) high, has

Air rights are a component of zoning height regulations

for built structures. Air rights give the property owner the

If a building is shorter than the maximum height, the

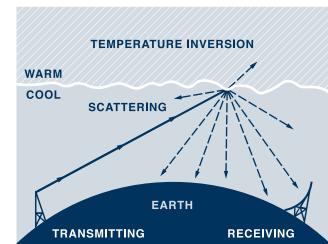
difference can be sold or otherwise transferred to another

property owner, allowing them to exceed the zoning

permission to build to the upper height limit allowed.

limitation by that same amount, when permitted.

also been recommended as the vertical limit of a nation's



TROPOSCATTER

PUBLIC RADIO

Frequency: 100-108 FM

Aerial: 1-1.5 Extendable

Input: Twin CD and Mixer or Mike

Output: Minijack for headphones or to amplifier

Above, the *Pirate Radio Briefcase*, by British anarchitects

the Space Hijackers, is "a complete pirate radio station in

a case. Hold parties wherever you want." This mobile

radio transmitter contains "a fully operational pirate radio

station complete with twin CD players, mixer, amplifier,

speakers, transmitter, and aerial." Also available from

Space Hijackers, the *Pirate Radio Jacket* – "dapper dress"

SKYWAVE

for pirate radio mischief making rude boys."

Size: Briefcase

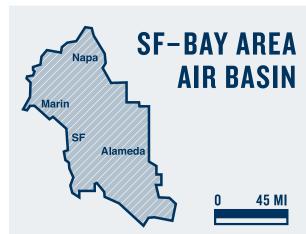
Power: 9-14V

Troposcatter is a way to communicate across long distances using microwave radio signals. It utilizes the tropospheric scatter phenomenon, by which a signal directed at the tropopause in a tight beam is refracted and randomly scattered while passing through the moist, turbulent troposphere. Most of the transmitted information is lost through scattering, so a high-gain dish antenna or a billboard antenna is used. Troposcatter can be utilized for long-distance communication when supported by fixed or mobile relay stations from 180 to 300 miles apart, but it can also cause interference. Troposcatter was developed during the Cold War for long distance, point-to-point information transmission when high capacity and reliability were required. It has

largely been replaced by satellite communication but may be revived because of orbital and spectral congestion.

0 KM / 0 MI

Sea level is the average ground height of the sea. The atmosphere has significant variations in pressure and temperature with altitude, which define a number of atmospheric layers. The boundaries between these are marked by abrupt transitions, known as the tropopause. stratopause, mesopause, and thermopause.



"The San Francisco Bay Area Air Basin is comprised of a

single district, the Bay Area Air Quality Management

District, and consists of Napa, Marin, San Francisco,

Contra Costa, Alameda, San Mateo, and Santa Clara

counties, the southern portion of Sonoma County, and the

western portion of Solano County. The air basin currently

exceeds both the 24-hour and the annual State PM10

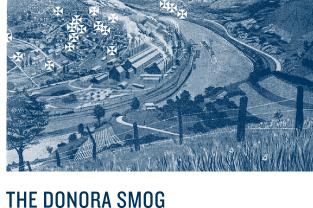
standards (particles smaller than 10 micrometers in diam-

- California Air Resources Board

eter), as well as the State annual PM2.5 standard."

SF-BAY AREA AIR BASIN





The 1948 Donora smog was a deadly ground-level smog

caused by a combination of particulate pollution from

smelting at Donora Zinc Works and fog trapped by an air

inversion. The smog sat over Donora, Pennsylvania, for

five days, darkening the skies. It sickened 6,000 of the

town's 14,000 residents and killed twenty people. Anger

at the widespread illness and deaths caused by the smog

spurred the first movement for air quality regulation in the

United States. It culminated in the Clean Air Act in 1963.

The act established funding for study and cleanup of air

pollution. The Donora Smog Museum, a storefront collec-

tion of artifacts documenting the smog and its aftermath,

opened to the public in 2008.

- Seth Zuckerman, Worldchanging Blog

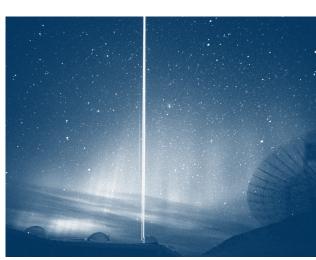




U.S. Air Force property, in 2015 the facility was transferred

from the Air Force to the University of Alaska, Fairbanks.

LIDAR (LIGHT DETECTION & RANGING) Lidar is similar to radar, utilizing the length of time from The High Frequency Active Auroral Research Program (HAARP) is an ionospheric research station. Its site, north transmission of a signal to the detection of the reflected of Gakona, Alaska, was chosen for its location in the aurosignal to determine the distance to an object, but using laser light instead of radio waves. It is used to study noctilucent ral region, above which geographically limited ionospheric features occur. These include the auroral electrojet, an unclouds and other phenomena in the middle atmosphere. predictably occurring high-powered electrical current. With "This image has beams from two lidar systems, one that an array of 180 antennas, "the most prominent instrument does Rayleigh scattering from all atmospheric gases and at the HAARP Station is the Ionospheric Research Instrument (IRI), a high-power radio frequency transmitter facility operating in the HF band." HAARP has been the subject of speculative and popular interest owing to its size and funding and because stated research goals included "iono-In addition to the two lidar beams, you can also see optical spheric enhancement technology for radio communications domes that house various camera systems to measure the and surveillance" and "active or interactive" experiments aurora borealis and a (blurry, moving) radar antenna also utilizing high frequency (HF) transmitting and "passive collecting information about the aurora." monitoring." Formerly co-managed by the United States Office of Naval Research and the University of Alaska on



one that is tuned to resonate with sodium atoms (which come from meteors ablating in the upper reaches of the atmosphere). The systems are located at the Sondrestrom Upper Atmospheric Research Facility in western Greenland.

Craig Heinselman, Scientist

3. Ackerman, Spencer. "Tiny 2-Foot

Bomb Could Be 'Months' Away Fron

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Image: Networked Weapons, from

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ATOMIC TESTS IN THE ATMOSPHERE

Photo: U.S. Department of Energy,

WAR IN THE LOWER ATMOSPHERE

Stanford Very Low Frequency (VLF) Group



The smokestacks of container ships traveling in and out of

the San Francisco Bay leave long exhaust trails of conden-

sation in their wakes. The cloud trails, called ship tracks, can

be seen trailing graphically downwind from ships, resembling

Sulfur dioxide and other pollution particles in these ship

emissions "seed" cloud droplets and influence marine cloud

formation. The aerosols in ship tracks also trap outgoing

longwave radiation (radiation leaving the Earth), influencing

coast of California was captured by NASA's Aqua satellite

rainfall and climate, and rendering visible some environmental impacts of global trade. The above image of bright, crisscrossing ship tracks off the

airplane contrails.

on February 21, 2012.

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CHARTING THE SKY The 1967 Outer Space Treaty designated

use of the sky continued onward in a similar spirit. Satellites have been used for espionage since their first launches in 1957 and 1958. By the late twentieth century, they were being used to conduct war itself remotely. Telecom war is far more subtle than bombs in flight. We can now hide war in the sky; a transparent place has become a curtain. The curtain of transparency,

paradoxically, obscures the complex of

above us. Only when those projects are

fully visible will they be reconciled as the

agents of cultural and political effect that

they are. Until then, we will not be at home

with the sky, much less at home up in it.

political and technological projects at work

space as a site for peaceful purposes. It our geography. It was a new "place," but it banned the testing and deployment of defies our previously understood notions weapons in space, following the detonation of place. Its transparency let us see the of atomic bombs in the atmosphere in the stars above, so it seemed to be an empty early 60s. Yet after the treaty, geopolitical space to transit. Then a range of activities reached into space: explorers, scientists, militaries. businesses, and lawyers all went to work up there, extending their spheres of

influence into the atmosphere. The satellite era allowed the sky to be charted and better understood. Science laid out its layers: troposphere, stratosphere, mesosphere, thermosphere, exosphere. Within each layer lies a cultural legacy of missteps and discoveries, intertwined. Missteps leave footprints that press down on us from above. The climate

is changing because of pollution in the

lower atmosphere. Peaceful exploration

Since 1783, hot air balloons, airplanes,

and finally satellites have opened progres-

sively higher reaches of the sky to our Society and technology together push touch. As we have explored, we have tried to assimilate the sky as an added realm of back against the missteps: new little solar sails, first flown in 2010, may be able to haul space junk out of orbit. Pushback

against climate destabilization is a challenge of a greater order. First, our idea of the sky must be reconciled with what we do in it. Our actions there mapped and charted. The sky itself must be woven into the fabric of our societal sense of place. Megan Prelinger

of space is hampered by pollution in the

LAYERS OF THE **ATMOSPHERE** Cloud Code Chart. United States. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administra tion, National Weather Service, 1972.

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